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ABSTRACT

The extent to which sex differences on a mental rotation test were related to ocular dominance, handedness, and familial handedness was explored. The Vandenberg revision of the Shepard-Metzlar mental rotation test was administered to 206 college students. The test consisted of 20 criterion figures, each followed by two correct and two incorrect alternative figures. The correct alternatives were identical to the criterion sample but were presented in a rotated position. Immediately after finishing the rotation test, subjects answered a questionnaire designed to assess their perceived cognitive strategy used in solving the spatial task. Ocular dominance, handedness, and familial handedness were also assessed by questionnaire. The superior performance of males on the mental rotation test was highly significant ($p=.0001$). The most common strategy employed by both sexes in solving the spatial task was mental picturing: however, females used significantly more verbal strategies than males. Handedness, per se, was unrelated to spatial performance, but right handed females with familial sinistrality had lower spatial scores than those with no familial sinistrality. More females than males were found to be left eye dominant: left eye dominance in females, but not in males, was associated with lower spatial scores. (Author/RL)

SEX DIFFERENCES IN SPATIAL PERFORMANCE AS RELATED TO CEREBRAL LATERALIZATION

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Abstract

The Vandenberg revision of the Shepard-Metzlar mental rotation test was administered to 206 college students. Handedness, ocular dominance, and familial handedness were assessed by questionnaire. Subjective reports of perceived cognitive strategy used in solving the spatial task were also collected. The anticipated superior performance of males on the mental rotation test was highly significant ($p=.0001$). The most common strategy employed by both sexes in solving the spatial task was mental picturing, however females report using significantly more verbal strategies than males. Handedness, per se, was unrelated to spatial performance but right handed females with familial sinistrality had lower spatial scores than those with no familial sinistrality. Unexpectedly, more females than males were found to be left eye dominant and left eye dominance in females but not in males was associated with lower spatial scores.

Introduction

Persistent sex differences in spatial skills, with males showing higher performance levels have been reported for a wide variety of spatial tasks including map reading, spatial rotation, paper folding, chess playing, and many others. In his extensive review Harris (1978) reports that on many of these tests only 20-25% of the females reach or exceed the mean performance levels of males, and that on some tasks, significant differences appear in early childhood.

Maccoby and Jacklin (1974) conclude that male superiority on spatial skills, though not universally found in childhood, is fairly consistent in adolescence and adulthood, and that male advantage increases through the high school years to a level of .40 of a standard deviation.

Two distinct forms of spatial abilities are often separated and may represent independent or overlapping skills: 1) Perceptual (non-analytic) spatial visualization, including the imaginary movement of objects in space (as measured by such tests as Thurstone's paper folding and Shepard's mental rotation). 2) Analytic spatial orientation and the detection of spatial relations within complex configurations (Hidden figure, Kohs, Rod and Frame test) (Harris, 1978).

Whether or not the conventional spatial tests validly measure and accurately distinguish between these presumably different skills remains in question. In addition, relatively few so called spatial tests are thought to be entirely free of any linguistic mediation. There may be a wide variety of cognitive strategies that employ some kind of verbal mediation in the solution of spatial tasks (Eliot and Salkind, 1975).

It is possible that sex differences in spatial skills are in part a result of sex differences in cognitive style, perhaps due to female developmental precocity in verbal skills. Tapley and Bryden (1977) identified two distinct approaches used in solving mental rotation tasks which they labeled visual holistic and verbal analytic. Significantly more men than women reported using a visual holistic strategy. These authors also found that the Paivio Imagery test (Paivio, 1971) predicts spatial performance in males but not in females.

Wilson, Defries, McClearn, Vandenberg, Johnson and Rashad (1975) proposed that the magnitude of the sex difference is particularly great in spatial rotation tasks precisely because it is very difficult to employ verbal strategies, thus putting females at an even greater disadvantage. The Vandenberg revision of the Shepard-Metzlar Mental Rotation Test (Vandenberg and Kuse, 1978; Shepard and Metzlar, 1971) was selected for use in this study expressly because it seems to produce large and consistent sex differences across a wide age span and because subjects report that it is more difficult to solve verbally than other spatial tests.

Recurring findings have suggested that sex differences in spatial ability may be linked to hemispheric specialization for cognitive functions. Such measures of cerebral lateralization as dichotic listening and visual hemifield tests, as well as direct measures of cortical activity, have indicated that sex related differences do exist, though the nature of these differences remain obscure.

Handedness, as a gross measure of lateral dominance has been critically related to spatial functioning by Levy (1969, 1975), who postulates that both left handers and females exhibit spatial deficits because they are less well lateralized. This is hypothesized to result in greater verbal processing in the right hemisphere which in turn interferes with or inhibits right hemisphere spatial functioning.

Attempts to verify Levy's hypothesis have not produced clear evidence of support (Harris, 1978; Carter- Saltzman, 1979). Handedness is not a simple dichotomous dimension and degree and pattern of familial handedness appear to be as significant as personal handedness. For example, lesion studies show that patterns of aphasia and recovery of speech after unilateral damage depend not only on handedness but on familial handedness and sex as well (McGlone and W. Davidson, 1973). Carter-Saltzman (1979) reports that both right and left handers who had at least two left handed relatives had higher spatial scores than those with only one or no familial sinistrality. Furthermore, she concludes that the familial effects were additive and did not interact with sex. In studies where all three variables of sex, handedness and familial sinistrality have been measured (Lake and Bryden, 1976; Davidson, Schwartz, Pugash and Bromfield, 1976) differences between subgroups appear that would not otherwise have been identified.

The significance of ocular dominance as a manifestation of functional asymmetry is not well understood. Individuals consistently choose one of the two monocular views that are present. Choice is often not conscious and they are frequently unable to give an offhand report of which eye is dominant for them. The most common test for eye dominance is sighting dominance, with 65% of the population classified as right eye dominant, 43% as left eye dominant, and the remaining 3% as having variable dominance (Porac and Coren, 1976). These authors conclude that there is little evidence of sex differences in the proportion of right and left eyed sighters.

Kimura (1969) notes however, that in all five of her experimental groups, there were more left eyed females than left eyed males. In that sample, 19% of the men and 34% of the women were classified as left eye dominant ($p < .02$). Ehrlichman (1972) also found a non-significant trend toward more left eyed females and Porac and Coren (1975) report that 53% of the males in their sample showed consistent right eye preference across a number of tasks, as compared to only 38% of the females, ($p < .025$). The purpose of this study was to explore the extent to which sex differences on the mental rotation test were related to ocular dominance, handedness and familial handedness.

Methods and Procedure

The Vandenberg adaptation of the Shepard Metzlar Mental Rotation Test (Vandenberg and Kuse, 1978) was administered to 206 college students in class or in small group settings. This test consists of 20 criterion figures, each followed by two correct and two incorrect alternative figures, (see Figure 1).

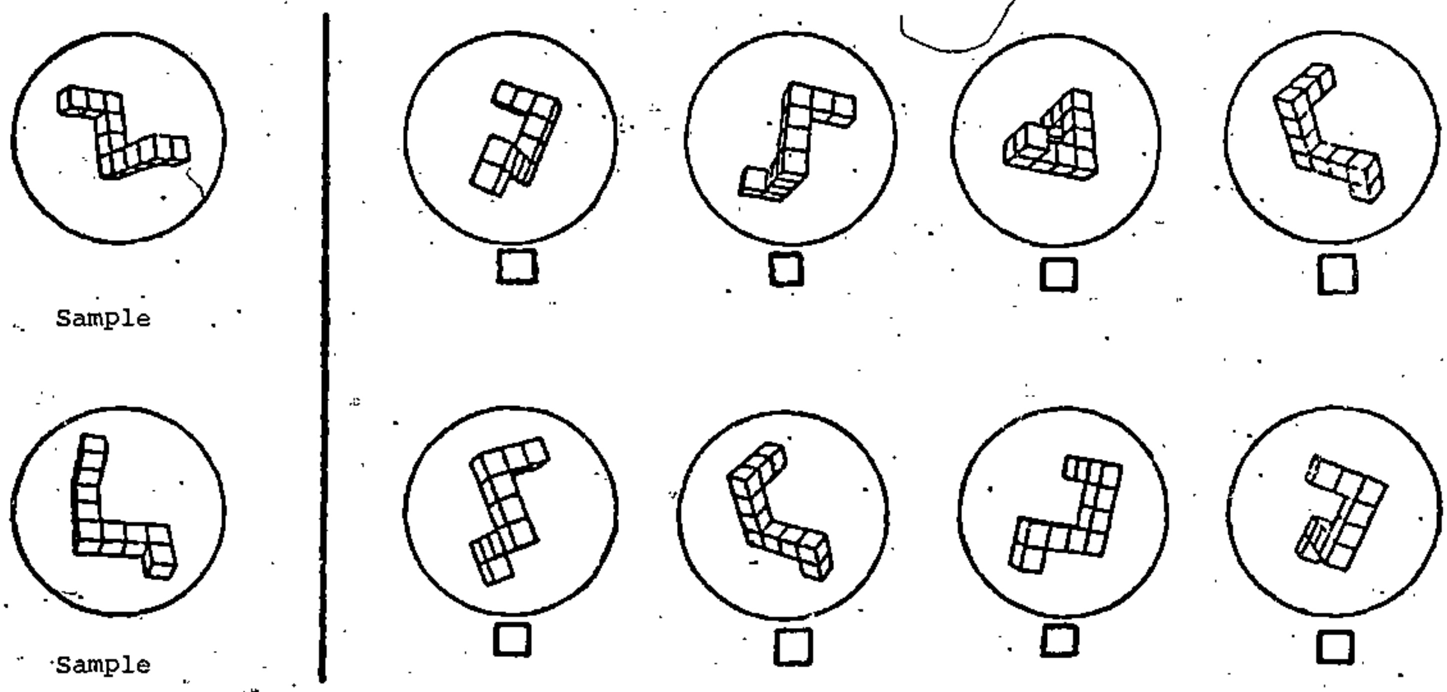

Figure I: Example of items in the Vandenberg Revision of the Shepard Metzlar Mental Rotation Test. Subjects select the two alternatives that are the same as the sample criterion figure on the left.

The correct alternatives are identical to criterion sample but are presented in a rotated position. Subjects respond by selecting both of the correct alternatives for each criterion item. According to Vandenberg's suggested procedure the test was administered in two parts with five minutes allowed for each.

Immediately after finishing this task subjects filled out a strategy questionnaire, designed to assess their cognitive strategy used in solving the spatial task. They rated on a five point scale the extent to which they solved the problems by: 1) thinking in words (talking to yourself), 2) counting blocks, 3) using your hands as aids, 4) picturing in your mind, 5) drawing. Manual dextrality was measured by Annett's Handedness Questionnaire (Annett, 1970) with additional questions added to assess familial handedness.

The following two questions were used to measure ocular dominance and were adopted because of their suitability for group administration:

1. When aiming at a distant target which eye would you normally close?
2. Hold your pencil in a vertical position about 10 inches from your eyes. Keep both eyes opened and line the pencil up with the edge of the doorway. Now close your left eye. Is the pencil still in line with the edge of the door?

Results

The expected sex difference in performance on the mental rotation test was confirmed in this study. Males scored significantly higher on the number of items completed, total number of correct items, number of correct pairs and % of correct items out of the total number completed (see Table 1).

	MALES	FEMALES	F	p
No. items completed	33.6	30.0	10.41	.001
No. correct	26.0	20.5	27.41	.0001
No. pairs correct	10.0	6.9	4.02	.046
% correct of total completed	78%	70%	3.79	.05
% correct pairs of total completed	30%	26%	.29	n.s.

Table 1. Sex Differences in Performance on the Mental Rotation Test. (The degrees of freedom for the above analysis were 1, 204).

The strategy questionnaire was designed to explore self-reported differences in cognitive style used in solving the mental rotation task. Results by sex are presented in Table II.

	MALES	FEMALES		p
Thinking in words (talking to yourself)	2.87	3.31	F=3.75	.05
Counting blocks	2.62	2.80		n.s.
Using hands as aids	1.44	1.86		n.s.
Picturing in your mind	4.70	4.56		n.s.
Drawing	1.24	1.56		n.s.

Table II. Response by sex to strategy questionnaire where 1=very little and 5=very much (df=1,203).

Both males and females indicated that the most frequently used strategy of which they were aware was picturing in their minds. The only significant sex difference supports the popular hypothesis that females use verbal strategy more than males. Females reported a greater use of "thinking in words-talking to yourself" while solving the spatial task (F=3.75, df=1,203, p=.05) than did males.

Further analysis of the strategy data according to dextrality revealed that left handed subjects felt they used their hands as aids in solving the spatial task significantly more than did right handed subjects (F=3.26, df=2,201, p=.04). Eye dominance and familial handedness were unrelated to strategy responses as was spatial performance.

Subjects were classified as right handers, left handers, or ambidextrals according to the following procedure based on their responses to Annett's 12 part handedness questionnaire:

1. Right handed - if at least 9 out of 12 responses were 'right' or 7 were 'right' and at least 3 of the remainder were in the 'either' category.

2. Left handed - if at least 9 out of 12 responses were 'left' or if 7 were 'left' and at least 3 were in the 'either category.

3. Ambidextrous - if less than 7 responses were in the same direction and/or the above criterion were not met.

The handedness distribution produced by this system of categorization was 80% right handed, 6.7 left handed, and 13.3% ambidextrous. There were no significant sex differences in the distribution and no relationship between eye dominance and handedness.

Analysis of spatial performance according to dextrality produced no significant main effects, and no sex by hand interaction.

The presence or absence of familial sinistrality (FS+, FS-) was assessed by the following question: "Are there any members of your immediate family (those related to you genetically) who write with their left hand or with either hand?" In response to this question 43% of our sample indicated FS+, 50% indicated FS-, and 7% did not know. Males with FS+ did not differ in spatial performance from males with FS-. There was, however, a non-significant trend for females with FS+ to score lower on the spatial test than females with FS- ($t=1.89$, $p=.06$).

A comparison of the spatial score of right handed subjects with FS+ and those with FS- showed a significant difference between these groups among females ($t=1.99$, $p=.05$), but not among males. Right handed females with FS+ scored lower on the spatial test than right handed females with FS-. Our left handed sample was too small to analyze handedness by familial handedness.

The two questions used to determine ocular dominance both measured sighting dominance, and thus we expected a high consistency of response. Results however, showed that 1/3 of the subjects answered these questions in opposite directions. It seems that this inconsistency is due mainly to the complex wording of the second question and may indicate the difficulty in measuring eye dominance in a large group testing situation. Chi square analysis by sex of the remaining 2/3 of the sample who responded consistently to both sighting questions showed that only 26% of the males as compared with 45% of the females were left eye dominant ($\chi^2=3.9$, $df=1$, $p=.05$).

Analysis of spatial performance by sex and ocular dominance revealed a sex by eye interaction. Analysis of the data using just those responses to the first eye-dominance question, thus including the entire 206 subjects, revealed a significant sex x eye interaction ($F=10.76$, $df=1,202$, $p=.001$) according to performance on the spatial task (see Figure II). Right eyed females had higher spatial scores than left eyed females.

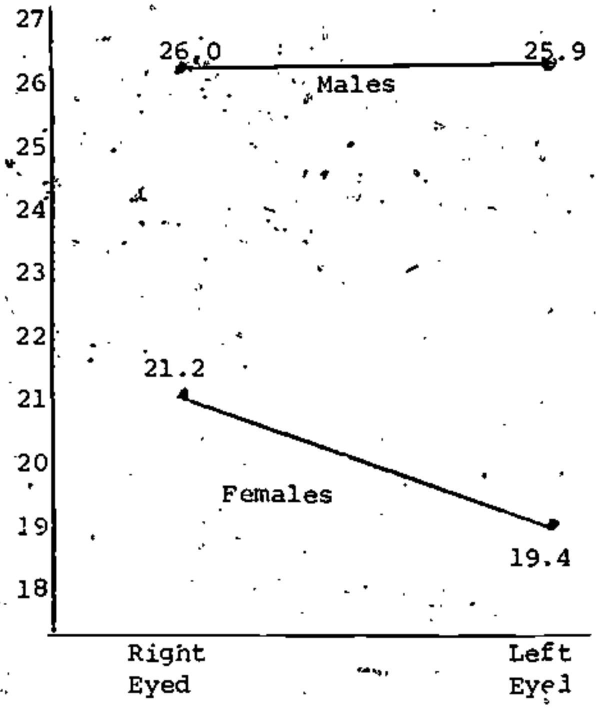

Figure II: Mean Score on the Mental Rotation Test for Right and Left Eye Dominant Males and Females. (Sex by eye interaction, $F=10.76$, $df=1, 202$, $p > .001$)

Discussion

The highly significant sex difference in spatial performance found here is consistent with the large body of literature which indicates that this difference is of substantial magnitude, and fairly universal among adults. Our results also support those of Vandenberg and Kuse(1978) and Tapley and Bryden (1977) who found sex differences with this particular mental rotation test. Since time pressure was a definite factor in this test, the finding that males completed significantly more items than females may imply either a difference in speed of mental rotation or a difference in cognitive style. Tapley and Bryden found that sex differences in speed of reaction increase as the degree of rotation between the figures increases, which they interpret as indicating a sex difference in speed of mental rotation.

Petersen and Wittig (1979) note that measures of response time may help to differentiate verbal from non-verbal cognitive strategies since verbal normally takes longer than visual. The fact that males in our sample completed more items within the time constraints can be viewed as indirect evidence that they were using a more visual approach. Males were not only faster but also more accurate, indicating that there was no speed-accuracy trade off among female subjects.

The Mental Rotation Task was expressly chosen for use in this study because it has been described as very difficult to solve by the use of verbal strategies. Even so, females reported that they "thought in words-talked to themselves" more often than did males. This finding is in agreement with the general supposition that females more often employ verbal strategies to solve spatial tasks. Not all tasks can be solved by using different strategies but when a task can be performed by either left or right hemispheric mechanisms, Kimura (1969) concludes that males tend to use right hemisphere, nonverbal systems, whereas females may tend to employ left hemisphere verbal processes because of their more developed verbal skills. Our findings confirm this. In a post-experimental interview following completion of a mental rotation task, Tapley and Bryden (1977) also found that more men than women reported using a visual holistic approach in contrast to a verbal analytic one.

Although this strategy difference emerged between the sexes, our data do not provide support for the suggestion that such differences could simply account for the main effect for sex on the spatial rotation task. No significant correlation was obtained between any item on the strategy questionnaire and actual spatial performance.

Tapley and Bryden (1977) also found no relationship between preferred strategy and accuracy of response but they did find one with rate of response for males. Those males who reported using visual strategies were faster at mental rotation than males who claimed to mix visual and verbal strategies. For females the situation was reversed. Women who used visual strategies were slow rotators, while women who were better verbal imagers had high spatial scores on the Differential Aptitude.

The nature of the task may be quite important in understanding the interplay between verbal and visual strategies. Tucker (1976) suggests that it is predominantly synthetic visuospatial functions for which the right hemisphere is specialized in males. Tucker believes that females use their left hemisphere in perceptual synthesis and that both sexes rely upon both hemispheres when perceptual analysis is required. In a study which measured electro-cortical activity, Ornstein, Johnstone, Herron and Swencionis (1979) found that while other spatial tasks engage the right hemisphere, mental rotation engaged the left hemisphere and produced a pattern of activation that was similar to verbal tasks. They conclude that the complexity of the task is a crucial factor and that when the task becomes sufficiently complex, a verbal analytic strategy becomes significant regardless of whether the problem is verbal or non-verbal.

One interpretation of these findings is that mental rotation is simply more verbal in females than males, but not necessarily less efficient because it is more verbal. It may be quite "natural" for verbal processes to play an important role in what have been labeled "non-verbal" activities, and females apparently make greater use of such verbal mediation. This claim is supported not only by data in normal subjects reviewed above, but also by brain damage evidence. McGlone and Kertesz (1973) found that following injury to the left hemisphere the degree of language impairment is predictive of visuospatial disability in females but not in males. It should be pointed out that greater use of verbal strategies does not necessarily imply left hemisphere involvement since the right hemisphere in females has greater control over certain verbal functions than does the right hemisphere in males (McGlone, 1977).

The relationship between dextrality and spatial ability appears to be minimal, especially in males. McKeever and VanDeventer (1977) also report no spatial differences due to handedness within or across sex. In their sample as in ours, left handed males tended to score higher spatially than right handed males. Clearly, dextrality alone is an insufficient predictor of spatial skill, contrary to Levy's hypothesis that left handers are likely to be less lateralized and thus poorer at such tasks.

The presence or absence of familial left handedness continues to surface as a more important factor than handedness itself in explaining sex differences, since those with familial sinistrality show systematically different lateralization of cerebral function from those with none, (Hardyck and Petrinovich, 1977; Davidson, Taylor, Saron and Stenger, 1979). Our left handed sample was too small to allow for analysis on the basis of familial handedness, however our findings for right handers indicates that the presence of familial sinistrality is associated with low spatial scores in females but not in males. Lake and Bryden (1976) also report that familial left handedness has a different effect on females than males. They found that regardless of handedness, females with familial sinistrality showed less laterality in dichotic listening, whereas males with familial sinistrality showed the typical pattern of right ear superiority. They conclude that handedness as a predictor of ear asymmetry is a function of familial sinistrality. Interestingly, heritability of handedness may be associated with sex, since left handed females tend to produce more left handed offspring than do left handed males (Kaufman, 1973).

The relationship between ocular dominance and lateral dominance is undetermined with as many studies concluding a low positive relationship as those that find none. Here again, sex differences emerged. Both Porac and Coren (1975) and Gur and Gur (1977) found a positive association between handedness and sighting dominance in males but no association between these factors in females. These authors note that the distribution of right eyed scores in their male population showed a shift toward the extreme right in comparison with females. If the notion of degree of eye dominance is introduced, this seems to imply that males show greater lateralization along this continuum. Again, we find the conclusion reported in many studies, that females are less well lateralized. The Gurs explain that while the determinants of ocular dominance remain unknown, whatever they are, they appear to operate in somewhat different ways in males and females.

Though a great many studies have explored cerebral lateralization and spatial ability, very few have bothered to look at eye dominance. Our results regarding eye dominance are intriguing. First they support the sporadic findings of greater left eye dominance among females. Second, to the best of our knowledge, this is the first time that eye dominance has been associated with level of spatial performance.

As noted earlier, Kimura (1969) concluded that there was a sex difference in incidence of left eyedness in her right handed population but she found no relationship between ocular dominance and dot location skill. Why should left eye dominance be associated with lower spatial performance? Hayashi and Bryden (1967) found no relationship between visual field superiority and sighting dominance. Right eyed sighters are reported however to be more consistent in their sighting preference than left eyed sighters, (Friedlandar, 1971). Perhaps this greater inconsistency of sighting dominance somehow interferes with visuospatial processing in females.

If it is true that females have a higher incidence of left eye dominance, and if as has been extensively reported, more females than males are right handed, than a higher percent of females would have mixed laterality, (contralateral eye-hand dominance). In fact, males appear more likely to have ipsilateral eye-hand dominance than are females, a condition thought to be somewhat advantageous for certain types of spatial tasks since better sensorimotor coordination is associated with it (Porac and Coren 1975). Mixed dominance may be associated with learning disability in children (Wold, 1968), and with differences in field dependency in non-pathological samples (Dawson, 1972). Perhaps the higher incidence of mixed laterality in females is somehow related to depressed spatial functioning and should be considered in future research.

The explanation for why left eye dominance is more frequent in females is not entirely clear. Porac and Coren (1976) hypothesize that environmental pressure on males to acquire aiming and throwing skills may result in greater ipsilateral eye-hand dominance and thus perhaps a higher incidence of right eye dominance. That socialization factors may be important is also suggested by the fact that girls who view themselves as more masculine had better spatial performance, and that male gender preference is associated with superior spatial scores in both boys and girls (Nash, 1975). Ehrlichman (1972) reports that females with high "femininity" as measured by a masculinity-femininity scale, also tended to have a higher incidence of left eye dominance.

These studies indicate that highly feminine females have lower spatial scores on the one hand, and a higher incidence of left eye dominance on the other. We in turn found that left eye dominance is associated with low spatial scores. Just how sex role orientation relates to ocular dominance and to spatial ability certainly merits further exploration.

Eye dominance is a complex phenomenon, consisting of several independent factors including sighting, sensory, and acuity dominance which may not be highly intercorrelated (Coren and Kaplan, 1973). We measured only one of these dimensions--sighting dominance. In addition, ocular dominance is likely to vary along a continuous dimension of degree of eyedness, and our procedure did not allow for measurement of that variability. Replication using more sensitive and reliable measures of ocular dominance are necessary to explore more precisely the relationship between eye dominance and spatial ability which these findings suggest may be important.

References

Annett, M. A Classification of hand preference by association analysis. British Journal of Psychology, 1970, 61, 303-321.

Carter-Saltzman, L. Patterns of Cognitive Functioning in Relation to Handedness and Sex-Related Differences. In M. A. Wittig and A. C. Petersen (Eds.) Sex Related Differences in Cognitive Functioning. N.Y.: Academic Press, 1979.

Coren, S. and Kaplan, C. P. Patterns of ocular dominance. American Journal of Optometry and Archives of the American Academy of Optometry, 1973, 50, 283-292.

Davidson, R. J. Schwartz, G. E., Pugash, E. and Bromfield, E. Sex differences in patterns of EEG asymmetry. Biological Psychology, 1976, 4, 119-138.

Davidson, R. J., Taylor, N., Saron, C. and Stenger, M. Individual Differences and Task Effects in EEG Measures of Hemispheric Activation. II: Effects of Sinistrality. To be presented at the Society for Psychological Research, Cincinnati, Ohio, October, 1979.

Dawson, J. L. M. Temne-arunta hand/eye dominance and cognitive style. International Journal of Psychology, 1972, 7, 219-233.

Ehrlichman, H. Hemispheric Functioning and Individual Differences in Cognitive Abilities. Dissertation Abstracts International. 1972, 33, 2319B.

Eliot, J. and Salkind, N. J. Children's Spatial Development. Springfield, Ill. Charles Thomas, Pub. 1975.

Friedlander, W. Some Aspects of Eyedness. Cortex, 1971, 7, 357-371.

Gur, R. E., Gur, R. C. Sex differences in the relations among handedness, sighting dominance and eye-acuity. Neuropsychologia, 15, (4-5), 585-590.

Hardyck, C. and Petrinovich, L. Left Handedness. Psychological Bulletin, 1977, 84(3), 385-404.

Harris, L. J. Sex differences in spatial ability: Possible environmental, genetic, and neurological factors. In M. Kinsbourne (Ed.) Hemispheric Asymmetries of Function. Cambridge, England: Cambridge University Press, 1978.

Hayashi, T. and Bryden, M. Ocular dominance and perceptual asymmetry. Perceptual and Motor Skills, 1967, 25, 605-612.

Kaufman, P. K. Genetic, Physical and Psychological Correlates of Handedness and Eye Dominance. Dissertation Abstracts International, 1975, Vol 35, 12B, 5939-B.

Kimura, D. Spatial localization in left and right visual fields. Canadian Journal of Psychology, 1969, 23, (6).

Lake, D. and Byrden, M. Handedness and sex differences in hemispheric asymmetry. Brain and Language, 1976, 3, 266-282.

Levy, J. Psychobiological implications of bilateral asymmetry. In S. J. Dimond, and J. G. Beaumont (Eds.), Hemispheric Function in the Human Brain. N.Y.: Wiley, 1975.

Levy, J. Possible basis for the evolution of lateral specialization of the human brain. Nature, 1969, 224, 614-615.

Maccoby, E. and Jacklin, C. N. The Psychology of Sex Differences, Stanford: Stanford University Press, 1974.

McGlone, J. Sex differences in the cerebral organization of verbal functions in patients with unilateral brain lesions. Brain, 1977, 100, 775-793.

McGlone, J. and Davidson, W. The relation between cerebral speech laterality and spatial ability with special reference to sex and hand preference. Neuropsychologia, 1973a, 11, 105-113.

McGlone, J. and Kertesz, A. Sex Differences in Cerebral Processing of Visuospatial tasks. Cortex, 1973b, 9, 313-320.

McKeever, W. and VanDeventer, A. Failure to confirm a spatial ability impairment in persons with evidence of right hemisphere speech capability. Cortex, 1977, 13, 321-326.

Nash, S. C. The relationships among sex-role stereotyping and sex difference in spatial visualization. Sex Roles, 1, no. 1, 1975.

Ornstein, R. Johnstone, J. Herron, J. and Swencionis, C. Differential right hemisphere engagement in visouspatial tasks. Submitted to Neuropsychologia, 1979.

Paivio, A. Imagery and Verbal Processes, N.Y.: Holt, Rinehart, and Winston, 1971.

Petersen, A. and Wittig, M. A. Sex-Related Differences in Cognitive Functioning. N.Y.: Academic Press, 1979.

Porac, C. and Coren, S. Is sighting dominance a part of generalized laterality? Perceptual and Motor Skills, 1975, 40, 763, 769.

Porac, C. and Coren, S. The dominant eye. Psychological Bulletin, 1976, 83, (5), 880-897.

Shepard, R. and Metzlar, J. Mental rotation of three-dimensional objects. Science, 1971, 171, 701-703.

Tapley, M. S. and Bryden, M. P. An investigation of sex differences in spatial ability: mental rotation of three-dimensional objects. Canadian Journal of Psychology. 1977, 31(3), 122-130.

Tucker, D. Sex differences in hemispheric specialization. Neuropsychologia, 1976, 14, 447-454.

Vandenberg, S. and Kuse, A. Mental rotations, a group test of three-dimensional spatial visualization. Perceptual and Motor Skills, 1978, 47, 599-604.

Wilson, J. Defries, J., McClearn, G., Vandenberg, S., Johnson, R., and Rashad, M. Cognitive abilities: Use of Family data as a control to assess sex and age differences in 2 ethnic groups. International Journal of Aging and Human Development, 1975, 6, 261-276.

Wold, R. M. Dominance-fact or fantasy: Its significance in learning disabilities. Journal of the American Optometric Association, 1968, 39, 908-916.